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# Predicting Ambulance Diversion in an Adult Emergency Department using a Gaussian Process

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*When the Emergency Department (ED) reaches a critical level of overcrowding, it diverts ambulances to other hospitals. We evaluated the accuracy of a Gaussian process for prediction of ambulance diversion using March 1, 2005 – November 30, 2005 data. The area under the receiver operating characteristic curve (AUC) for 120 minutes in advance was 0.93 (SE: 0.19). The instrument demonstrated a high AUC and may be used to alert ED managers earlier of a diversion episode.*

## INTRODUCTION

Emergency department (ED) overcrowding is no longer a problem of large urban hospitals. EDs must initiate ambulance diversion when overcrowding reaches a critical level. This creates a safety risk for any patient in the ED. Furthermore, it exposes ED staff to higher stress potentially leading to critical delays and increased rates of medical errors. Many factors influence the ED's input, throughput, and output capacity; thus it is a challenge to identify the need for ambulance diversion in advance. Predicting overcrowding episodes in advance ED clinicians and managers can be proactive about initiating relief measures rather than reactive. We applied a machine learning technique known as a Gaussian process (GP) to predict episodes of ambulance diversion. GPs are an extension of the idea of a Bayesian artificial neural network, but with an infinite number of hidden nodes. Due to its Bayesian nature, GPs are not prone to overfitting.

## METHODS

The adult ED at Vanderbilt University Medical Center is an academic Level I trauma center with an annual patient volume of >55,000 encounters. The ED staff uses a computerized whiteboard for patient tracking and workflow. To predict diversion we used data from the whiteboard system for both patient information and operational statistics. Log files from Vanderbilt Life Flight were used as the gold standard for the hospital units' diversion times including the ED. The training set contained the initial times of all 99 ED diversion periods between March 1, 2005 and August 31, 2005. An additional 500 randomly selected time points, which were not within 30 minutes of a diversion period, were

added to the training set. The test set contained 44 diversion instances from September 1, 2005 – November 30, 2005. A randomly selected 500 data points were added to the test set which were not within 30 minutes of a diversion periods.

Four training and testing sets were created at 30 minute intervals ranging from 30 to 120 minutes prior to the time point in the data set. The GP was trained and tested on each of the four data sets. Variable selection was based on expert domain knowledge. Once the data sets were assembled, the data were Gaussian normalized. Performance was analyzed using the area under the receiver operator characteristic curve (AUC).

## RESULTS

The ten variables selected included diversion status of the critical care unit, diversion status of the medical/surgical unit, ED occupancy rate, waiting room count, average waiting room length of stay, number of patients who arrived by ambulance in the previous 30 minutes, the number of patients with the most severe acuity level (Emergency Severity Index 1), the number of patients with an Emergency Severity Index of 2, the number of boarding patients in the ED, and whether the time point was between 11AM and 11PM. Table 1 shows the results for predicting diversion with the 4 data sets.

*Table 1: Area under the receiver operator characteristic curve (AUC) for different time points.*

	30 mins	60 mins	90 mins	120 mins
AUC	0.97	0.94	0.95	0.94
SE	0.12	0.13	0.15	0.19

## DISCUSSION

The GP demonstrated high accuracy for predicting ambulance diversion up to two hours in advance. The system may help predict an expected, near-term ED overcrowding episode and allow managers to initiate short term strategies to alleviate or shorten the burden of impending ED overcrowding.

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